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TECHNICAL REPORT
71-22-FL

CONTROLLED ATMOSPHERE SYSTEM LABORATORY STUDIES ON CELERY

by
Harold Gorfien
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September 1970

UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

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Food Laboratory
U.S. Army Natick Laboratories
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FOREWORD

Previous studies by the U.S. Army Natick Laboratories have indicated that the use of controlled atmosphere could improve the quality, reduce spoilage and increase the storage life of lettuce and tomatoes intended for use by military organizations overseas. Because of these encouraging results, it was decided to conduct laboratory studies on the effects of a low-oxygen atmosphere on celery.

This work was performed under Production Engineering 2270.3. Mr. Harold Gorfien was the Official Investigator.

The author's wish to acknowledge the assistance of the Transfresh Corporation, Salinas, California in providing the test TECTROL* Controlled Atmosphere chests. Assistance of L. Klarman is acknowledged for writing programs for computer calculations of data.

* TECTROL is a registered trademark of Whirlpool Corporation

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ABSTRACT

Laboratory tests were conducted to determine the effect of controlled atmosphere on celery. Storage periods were 3 to 8 weeks. The data indicates that the use of controlled atmosphere results in celery which is greener in color, more turgid and of more intense celery flavor.

Significant reductions in spoilage of the soft rot type were found in celery which had been initially stored in controlled atmosphere. However, spoilage data were limited to 3 crops of celery only and must be viewed with caution. The fourth crop as represented by celery hearts, exhibited the least amount of spoilage. The data in this report also show that wrapped celery lost less moisture than unwrapped celery. The break-even point to defray the additional cost of a commercially available controlled atmosphere method of shipping is estimated to be in the range of 2.5% to 4.7% improvement in celery yield.

It is concluded that sufficient laboratory data, and information in the technical literature, is available to warrant a series of field tests on celery and other fresh fruits and vegetables shipped in commercial controlled atmosphere containers to military organizations overseas.

CONTROLLED ATMOSPHERE SYSTEM LABORATORY STUDIES ON CELERY

Introduction

Providing good quality fresh fruits and vegetables in sufficient quantity to meet the requirements of military personnel is a concern of the Armed Forces. Overseas shipment and storage periods are much longer than those for normal distribution to civilian markets within the Continental United States (CONUS). As a result, reductions in quality and increased spoilage are exhibited by perishable products prior to arrival and consumption overseas.

For the 12-month period from July 1969 to June 1970, Defense Personnel Support Center purchased 34,295,934 pounds of celery in the United States. The purchase price and the added cost of warehousing, handling and shipping both CONUS and overseas amounts to a substantial sum of money.

Previous laboratory and field test studies by NLABS have shown that there were advantages in using the TECTROL controlled atmosphere system for shipping lettuce overseas. Following this evidence, additional tests on lettuce were conducted with the Oxytrol controlled atmosphere system. This test series confirmed the previous findings as to the advantages of controlled atmosphere in the overseas shipment of lettuce. Advantages were also found by NLABS in holding tomatoes in a low-oxygen atmosphere (which is carbon dioxide free). It was decided therefore, to explore the feasibility of using controlled atmosphere as a means of extending the shelf-life of celery.

Previous related studies

Research on the post harvest storage of various crops including celery has increased within the past two decades. Treatments or techniques involving packaging materials, cooling methods and chemicals have been reported in the literature as affecting such celery quality factors as decay, green color retention, flavor, turgidity, crispness, pithiness and storage life. Very little information may be found on the affects of controlled atmosphere on celery.

Research conducted by the US Naval Supply Research and Development Facility in 1954 (1) demonstrated that celery in LSAT (moderate moisture vapor retention cellophane) lined crates had a longer storage life than celery in unlined crates. A series of studies on the effects of packaging and storage temperature on celery were then conducted by the USDA under contract to the Navy (2). The results showed that celery kept longer at 32°F. than at 38°F. In addition, celery stored without wrapping or bagging, or individually wrapped in parchment was wilted and tough when removed from storage. Celery which had been stored in polyethylene bags or liners retained crispness and tenderness without wilting. The original green color of Pascal celery was retained for a longer period with the use of polyethylene packaging. This was followed by a field test (3) conducted aboard a Navy supply ship. Bacterial soft rot was found to be the principal decay in both lined and unlined crates of celery. After 6 weeks storage at 36°F., 79 percent of the celery in polyethylene lined crates remained edible compared with 71 percent in unlined crates.

A comparison was made of hydrocooling and vacuum cooling on celery quality in 1962 (4). The method of precooling did not affect the quality of celery, but the use of top-ice during the 8-day holding period improved turgidity and salability. A relationship was established between pithiness and moisture loss in celery (5). The development of pithiness was associated with a decline in fresh and dry weight during storage.

Laboratory and field tests on lettuce, and laboratory tests on tomatoes have been conducted by NLABS, involving the extended period of time required to ship and store fresh produce overseas (14, 15, 16, 17, 18). These tests showed that controlled atmosphere would result in significant improvements in quality of lettuce and tomatoes with less loss due to decay. The findings on reduction of decay in tomatoes agree with those published by the U.S. Department of Agriculture (19). (Peaches and nectarines were also shown to have longer storage life under controlled atmosphere than in air in this U.S. Department of Agriculture study.)

Controlled atmosphere studies (6) conducted with celery indicated that oxygen levels between 1% and 5% can have a slight benefit in extending shelf life. Levels of oxygen below 1% were found to be harmful. Increased carbon dioxide was shown to reduce the quality of celery since injury become apparent when subsequent holding was in air. Where films of selective gas permeability were used (7), a modified atmosphere developed around the celery; the original green color of Pascal celery was retained for the longest period with non-perforated polyethylene bags.

Although there is very little information in the literature on the effects of controlled atmosphere on celery, there is abundant information on the use of controlled atmosphere for preventing quality degradation and decay in other agricultural crops. Asparagus spears held in 5% to 10% carbon dioxide had better market quality and less soft rot (8) than when held in air. Cabbage was found to have better green color retention and flavor (9) at low levels of carbon dioxide and oxygen, compared with air storage. Bananas (10) were found to ripen within 6 days in air; whereas, at low levels of oxygen and ethylene ripening was delayed 12 days. Decay rates in lemons were found to be reduced after 1 month storage in 7% to 8% oxygen (11). Apples (12) were found to be firmer, greener in color, and have less decay and less scald when stored under controlled atmosphere. Benefits ranging from slight to major attributable to the use of controlled atmosphere on 20 different vegetable and 17 different fruit types have been summarized in table form (13). Among the benefits listed are (a) extension of storage and transportation life, (b) inhibition of mold and decay, and (c) retention of green color and fresh flavor. It is possible that the principles involved in using controlled atmosphere to prevent loss of quality and decay in other agricultural commodities may also be effective with celery.

Research has been conducted on the effects of controlled atmosphere on the physiology associated with fruits and vegetables. The use of controlled atmosphere has resulted in a 28% to 36% reduction in the heat of respiration of peas, sweet corn, lima beans and apples (20). With lettuce at 41°F. under controlled atmosphere, the heat of respiration was reduced 50% (21). The use of carbon monoxide as part of the controlled atmosphere system could theoretically have an effect on the storage life of plant material by affecting some of the oxidizing enzymes in plants. Cytochrome oxidase can complex with, and O-diphenol oxidase is inactivated by carbon monoxide (22). Phenol oxidases have been associated with the browning of fruit and may be involved in flavor changes. An article (23) explaining the biological principles on which controlled atmosphere is based concludes with the following: "while atmosphere control is unlikely to replace refrigeration in the preservation of perishable produce, it will soon play an important part in its storage and transport especially for those kinds sensitive to low temperatures".

Methods and materials

The test plan was designed to determine the effect of controlled atmosphere on the storage life of celery. This involved shipping celery by railcar from the West Coast to the East Coast, holding the celery at 38°F. with and without controlled atmosphere under simulated overseas shipping conditions, and then transferring to a 38°F. chill box for an additional 2 to 5 weeks storage in air.

Four different crops of celery from California were obtained and stored as shown in Table 1.

TABLE 1. KEY TO CODING FOUR CELERY CROPS AND THEIR STORAGE PERIODS.

Celery Crop Code	Description and Packaging	Picking Time Prior to NLABS Procurement (days)	NLABS Initial Holding Period With or Without Controlled Atmosphere at 38°F. (weeks)	NLABS ADDITIONAL HOLDING PERIOD IN Air at 38°F.
A	Celery Naked Pack	10	3	4
B	Celery Naked Pack	10	3	4
C	Celery Hearts Individually Wrapped	10	3	4
D	Celery Individually Wrapped	10	2	5

U.S. No. 1 Grade Celery defined in Federal Specifications HHH-C-191f, celery, fresh was shipped by rail from California to Boston. Celery crop A was shipped conventionally in air. Celery crops code B, C & D were shipped under controlled atmosphere (2% oxygen, 2% carbon monoxide, 96% nitrogen). On arrival at NLABS the boxes of celery were randomly distributed among (1) a low-oxygen chest, and (2) an air chest (control), both set at 38°F.

The low-oxygen and the air chests are horizontal refrigerated boxes 36 7/8 inches high, 48 1/2 inches long and 27 7/8 inches deep with an internal storage volume of 15.6 cubic feet. These chests are thermostatically controlled and each has a fan for air circulation. The low oxygen chest has a transparent plastic lid for sealing the chest gas tight. This plastic lid has inlet and outlet parts for gas exchange.

Nitrogen was admitted to produce a low-oxygen level in the low-oxygen chest. Gas analyses were conducted on the low-oxygen chest at 48 to 66 hours intervals throughout the storage period. A Fisher Gas Partititioner Model 29A was used to determine the percentages of all gases present throughout the 2 to 3 week controlled atmosphere period. Air was added to the low-oxygen chest as required at 48-to 66-hour intervals to maintain the oxygen level within a range of 2% to 5%. Nitrogen made up the difference, since carbon dioxide produced by respiration was scrubbed out with hydrated lime. At the end of the 2 to 3-week storage period, the celery was removed from both the low-oxygen and control air chests and placed in air in a conventional chill box at 38°F.

Quality evaluations were made on the celery at periods ranging from 2 to 5 weeks later. Evaluation of the celery consisted of the following:

(a) Moisture loss - by weight as described in reference (7).

(b) Edible yield of celery - Removal of the butt, leaves, and other parts of celery considered unfit for table use due to discoloration or decay as described in reference (2). The remaining portion of the celery considered fit for table use was then weighed.

(c) Salability - by rating, in terms of overall appearance and absence of decay prior to trimming, on an arbitrary scale of 1 through 9 (9 = excellent, 8 = very good, 7 = good, 6 = fair to good, 5 = fair, 4 = fair to poor, 3 = poor, 2 = very poor, 1 = unacceptable); which is equivalent to the method described in reference (4).

(d) Turgidity - Stalk turgidity was described by rating on a scale of 1 through 9 as defined above under salability; which is equivalent to the method described in reference (4).

(e) Flavor - A flavor panel determing preference by rating paired samples of celery which had been trimmed to remove parts and decay considered unfit for use, hedonically from 1 to 9 (9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, 1 = dislike extremely).

(f) Severity of leaf decay and stalk decay - by rating on a scale of 1 through 5 (1 = none, 2 = trace, 3 = slight, 4 = moderate, and 5 = severe), as described in reference (4).

(g) Color - Describing celery color using the following methods:

(1) By visual examination using an arbitrary rating scale of 1 through 5 (1 = dark green, 2 = green, 3 = yellow-green, 4 = green-yellow, and 5 = yellow).

(2) A Color Eye tristimulus colorimeter with abridged spectrophotometer, and converting the reading into the Hunter system.

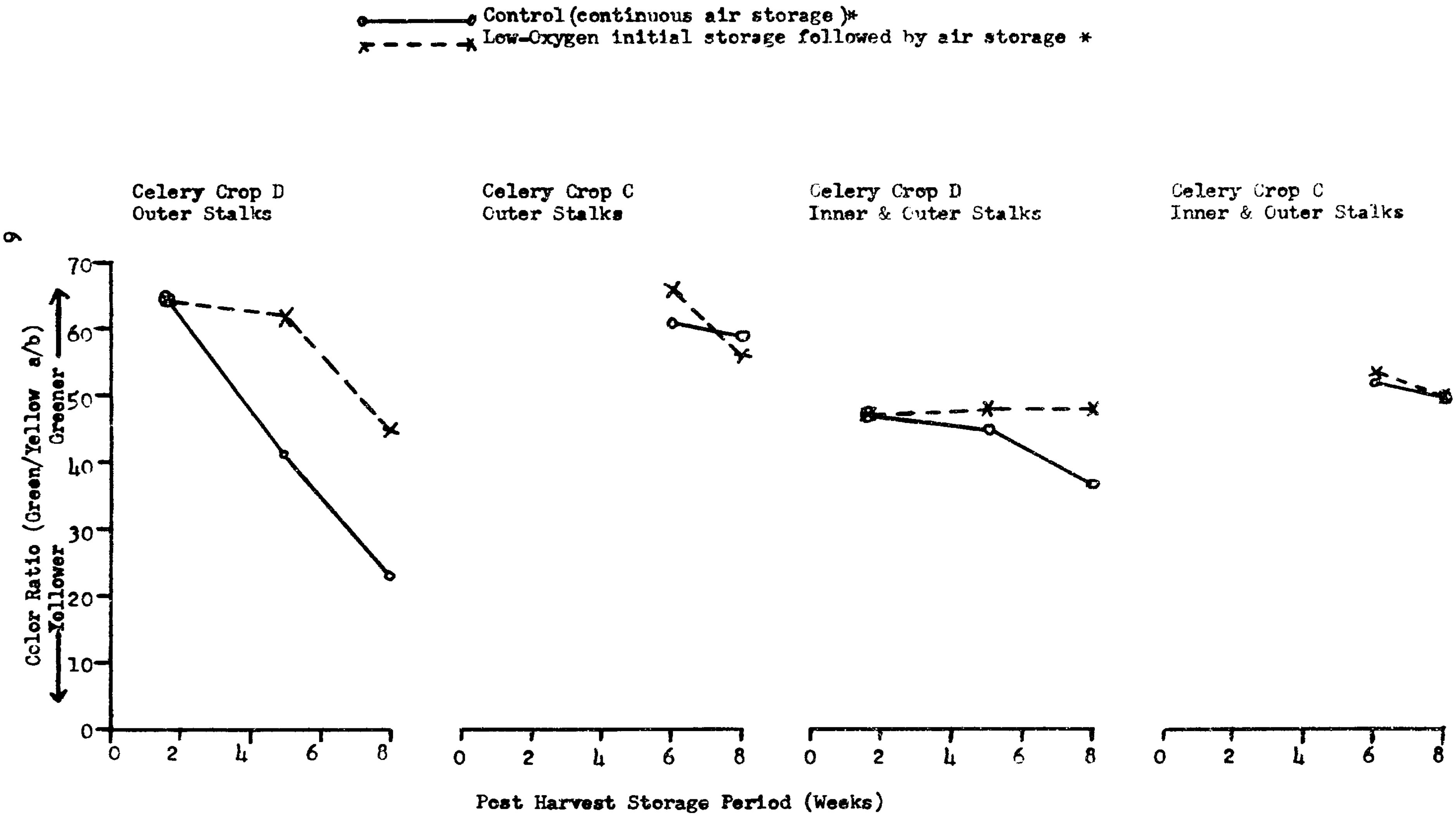
Results

Moisture loss. In all 4 celery crops there was less moisture loss in celery which had been stored under low-oxygen compared with celery stored in air. This is indicated by comparing the moisture losses at the time of removal of the celery from the low-oxygen chest (fourth week after picking), Figure 1. The data further show that under under refrigeration conditions unwrapped celery lost as much as 14 to 18% moisture within an eight week period. Commercial wrapping of celery in perforated polyethylene reduced the amount of moisture lost in the same period to 3 to 4%.

Edible Yield Celery. In three of the four celery crops a significant reduction in celery spoilage was observed with a resulting improvement in edible yield (Table 2), when low-oxygen (controlled atmosphere) was used for storage. The principal spoilage observed in the stalks was a soft rot type similar to Bacterial soft rot. The fourth crop (crop C) in which no difference was obtained, was celery hearts which had the least amount of spoilage in storage.

Celery Quality Factors. The celery was examined for various factors that have a bearing on celery quality such as salability, turgidity, flavor, color and decay. Average scores obtained by rating these factors and their significance are shown in Tables 3, 4, 5, and 6. In general, celery stored in low-oxygen was more salable in terms of appearance and absence of decay, greener in color, more turgid and had a more intense celery flavor. An example of the greener color difference as measured by the Color Eye instrument with data converted to Hunter Colorimeter values is shown in Figure 2. Average measurements for the outer stalks at specific time periods indicate the overall color of the celery in the package prior to trimming. Average measurements for the inner and outer stalks indicate the color of the trimmed ready-to-eat celery on the table. These measurements show that the outer stalks for celery crops C and D of the low-oxygen stored celery were greener than those of air stored celery, although little difference could be observed by the time the celery was trimmed and the inner and outer stalks were mixed as if served at the table.

Figure 2 COLOR COMPARISON OF CELERY HELD IN LOW-OXYGEN CONTROLLED ATMOSPHERE AND IN AIR



* All celery shipped for 10 days in Controlled Atmosphere. The Low-Oxygen stored celery was then held for 2 to 3 additional weeks in Controlled Atmosphere prior to air storage.

Table 2. EFFECT OF LOW-OXYGEN AND AIR (CONTROL) STORAGE ON CELERY EDIBLE YIELD

Crop Code (See Table 1)	Storage Times: INITIAL* at 38°F (weeks)	(plus)	ADDITIONAL* at 38°F in Air (weeks)	Average Edible Yield of Celery When INITIAL Storage Was: Low-Oxygen (%)	Control (%)	Significance**
A	4 (L)	plus	2	55.8		S
	4 (C)	"	2		49.9	
	4 (L)	"	4	50.4		
	4 (C)	"	4		37.5	S+
B	4 (L)	"	2	74.9		
	4 (C)	"	2		66.2	S+
	4 (L)	"	4	72.6		
	4 (C)	"	4		63.0	S+
C	4 (L)	"	2	86.0		
	4 (C)	"	2		84.5	NS
	4 (L)	"	4	83.6		
	4 (C)	"	4		82.5	NS
D	3 (L)	"	2	81.0		
	3 (C)	"	2		76.4	S+
	3 (L)	"	5	80.6		
	3 (C)	"	5		75.7	S+
A, B, C, D. Pooled Averages				73.1	66.9	S

* (L) = INITIAL storage period in Low-Oxygen controlled atmosphere including shipping period

(C) = INITIAL storage period in air (Control) including shipping period

ADDITIONAL storage period was in air

** Statistical analysis; S+=Significant at 1% level, S= Significant at 5% level, NS=Not Significant

TABLE 3. POST HARVEST QUALITY OF CELERY CROP A

Evaluation Indice	6 Weeks After Picking			8 Weeks After Picking		
	Low Oxygen Chest Initial Storage	Air Chest Initial Storage	Significance ****	Low-Oxygen Chest Initial Storage	Air Chest Initial Storage	Significance ****
Salability* (score)	6.7	5.3	S+	5.2	3.0	S+
Turgidity* (score)	7.1	5.7	S+	6.5	5.7	S+
Flavor Panel* (hedonic rating)	6.75	6.58	NS	6.92	5.33	S+
Leaf Color*** (score)	3.1	4.3	S+	3.4	4.7	S+
Leaf Decay** (score)	1.7	2.6	S+	2.8	4.1	S+
Stalk Color*** (score)	2.8	3.9	S+	3.7	4.5	S+
Stalk Decay** (score)	1.6	2.3	S+	2.7	4.2	S+

* Salability, turgidity and flavor panel rating scores (9 to 1). The higher the score, the better the salability, turgidity, and flavor panel rating.

** Decay rating scores (1 to 5). The lower the score, the less the decay.

*** Color rating scores (1 to 5). The lower the score, the greener the color. The higher the score, the yellower the color.

**** Statistical analysis: S+ = Significant at 1% level, S = Significant at 5% level, NS = Not Significant

TABLE 4. POST HARVEST QUALITY OF CELERY CROP B

Evaluation Indice	6 Weeks After Picking			8 Weeks After Picking		
	Low-Oxygen Chest Initial Storage	Air Chest Initial Storage	Sig-nifi-cance ****	Low-Oxygen Chest Initial Storage	Air Chest Initial Storage	Sig-nifi-cance ****
Salability* (score)	6.7	5.1	S+	5.8	4.1	S+
Turgidity* (score)	7.0	6.0	S+	5.6	4.5	S+
Flavor Panel * (hedonic rating)	7.31	6.16	S	6.67	5.75	S+
Leaf Color*** (score)	2.8	3.7	S+	3.2	4.0	S+
Leaf Decay** (score)	1.9	3.0	S+	2.7	3.6	S+
Stalk Color*** (score)	2.3	3.4	S+	3.0	4.1	S+
Stalk Decay** (score)	1.3	2.4	NS	2.6	3.1	S+

* Salability, turgidity and flavor panel rating scores (9 to 1). The higher the score, the better the salability, turgidity, and flavor panel rating.

** Decay rating scores (1 to 5). The lower the score, the less the decay.

*** Color rating scores (1 to 5). The lower the score, the greener the color. The higher the score, the yellower the color.

**** Statistical analysis: S+ = Significant at 1% level, S = Significant at 5% level, NS = Not Significant

TABLE 5. POST HARVEST QUALITY OF CELERY CROP C

Evaluation Indice	6 Weeks After Picking			8 Weeks After Picking		
	Low-Oxygen Chest Initial Storage	Air Chest Initial Storage	Significance ****	Low-Oxygen Chest Initial Storage	Air Chest Initial Storage	Significance ****
Salability * (score)	7.4	7.6	NS	6.5	6.1	NS
Turgidity* (score)	7.0	7.2	S+	6.7	5.9	S
Flavor Panel* (hedonic rating)	7.83	7.33	NS	7.42	6.50	NS
Leaf Color*** (score)	2.6	2.6	NS	2.2	2.6	S
Leaf Decay** (score)	1.5	1.5	NS	2.2	3.0	S+
Stalk Color*** (score)	1.5	1.5	NS	1.9	2.3	S
Stalk Decay** (score)	1.0	1.1	NS	1.8	2.2	NS

* Salability, turgidity and flavor panel rating scores (9 to 1). The higher the score, the better the salability, turgidity, and flavor panel rating.

** Decay rating scores (1 to 5). The lower the score, the less the decay.

*** Color rating scores (1 to 5). The lower the score, the greener the color. The higher the score, the yellower the color.

**** Statistical analysis: S+ = Significant at 1% level, S = Significant at 5% level, NS = Not Significant

TABLE 6. POST HARVEST QUALITY OF CELERY CROP D

Evaluation Indice	5 Weeks After Picking			8 Weeks After Picking		
	Low-Oxygen Chest Initial Storage	Air Chest Initial Storage	Significance ****	Low-Oxygen Chest Initial Storage	Air Chest Initial Storage	Significance ****
Salability * (score)	7.1	6.7	NS	6.5	6.1	NS
Turgidity * (score)	7.7	7.4	NS	6.9	6.7	NS
Flavor Panel * (hedonic rating)	7.21	6.43	NS	7.15	6.77	NS
Leaf Color *** (score)	2.1	2.9	S+	2.5	2.9	NS
Leaf Decay ** (score)	1.9	2.5	S	2.4	2.9	S
Stalk Color *** (score)	2.3	2.9	S+	2.5	2.6	NS
Stalk Decay ** (score)	1.1	1.4	NS	1.5	1.7	NS

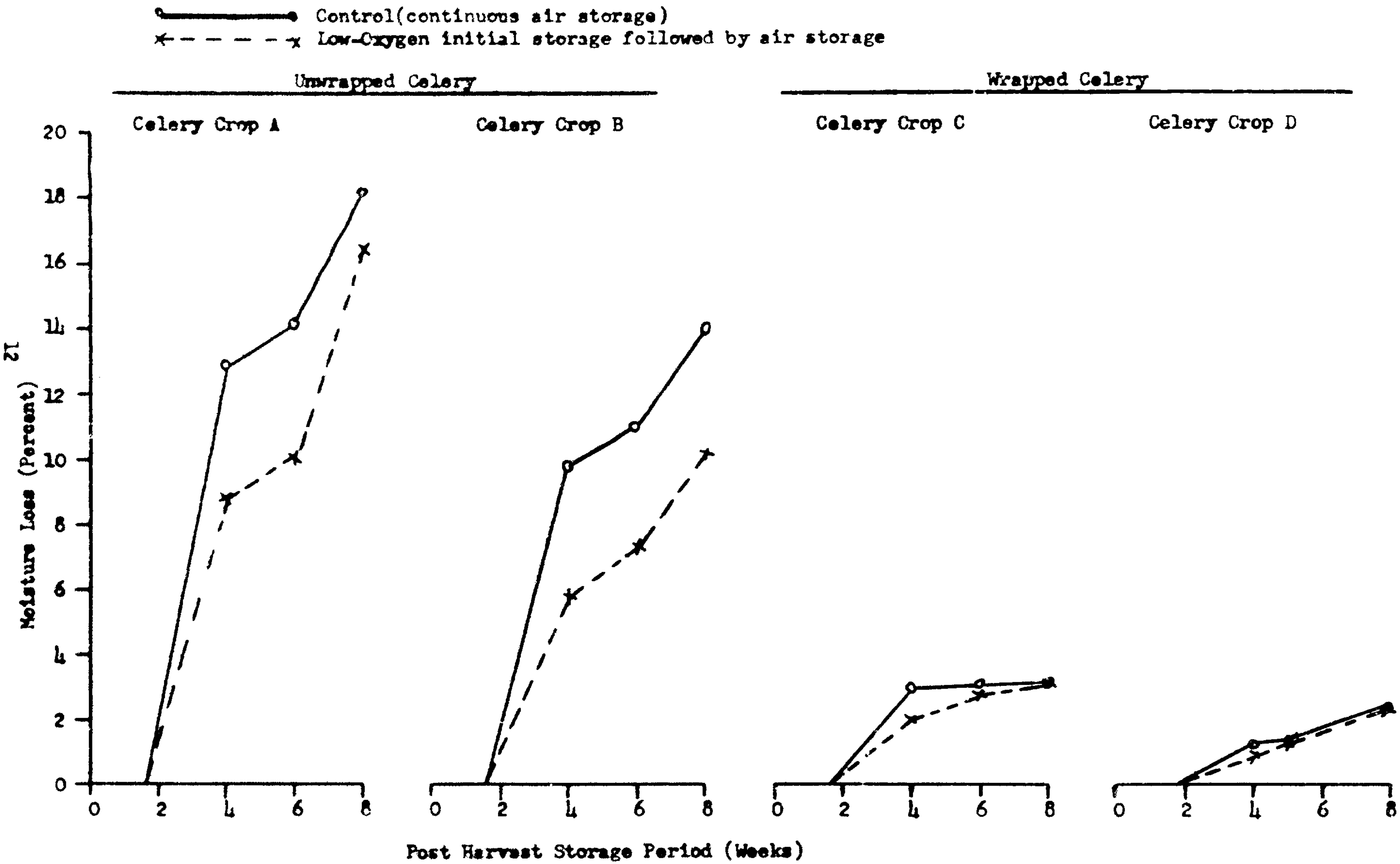
* Salability, turgidity and flavor panel rating scores (9 to 1). The higher the score, the better the salability turgidity, and flavor panel rating.

** Decay rating scores (1 to 5). The lower the score, the less the decay.

*** Color rating scores (1 to 5). The lower the score, the greener the color. The higher the score, the yellower the color.

**** Statistical analysis: S+ = Significant at 1% level, S = Significant at 5% level, NS = Not Significant

Figure 4 MOISTURE LOSS COMPARISON OF CELERY HELD IN LOW-OXYGEN CONTROLLED ATMOSPHERE AND IN AIR



Discussion

Evidence has been developed that the use of low-oxygen controlled atmosphere for initially storing celery results in celery which is greener in color, more turgid and of more intense celery flavor than air storage. The U. S. Department of Agriculture (7) has previously shown that celery stored in polyethylene bags or liners retained the original green color for a longer period, was not wilted and retained crispness and tenderness, compared with a reduction in these quality characteristics when celery was stored unwrapped or wrapped in parchment. The retention of green color was ascribed as a beneficial effect of the modified atmosphere that developed in the polyethylene bag. However the lack of wilting, and retention of crispness and tenderness were attributed to high humidity within the polyethylene packages. In this same report, information was developed which showed that trimming losses in celery wrapped in non-perforated polyethylene bags were significantly lower than with unwrapped celery; no significant trimming loss differences were found between celery wrapped in perforated or non-perforated bags. The fact that the oxygen levels were much lower in the non-perforated bags along with the lack of significant difference in trimming losses in perforated bags may have lead the research workers to conclude that the modified atmosphere had little to do with the keeping quality of celery in contrast to the highly beneficial effects of high humidity within the packages. An examination of the data presented in this same report revealed that there was little difference in weight loss between celery stored in non-perforated polyethylene or perforated polyethylene bags. There was a difference in the atmosphere in the bags. The non-perforated polyethylene bag had an oxygen level at 38°F. approximately 1/2 that of air, and the perforated polyethylene bag had an oxygen level approximately equal to that in air. A reinterpretation of this data infers that since the weight losses on storage were about the same, the relative humidity in and/or around the bags were about equal. Therefore, the differences in trimming losses observed might have been due in part to modified atmospheres. The data shown in Table 2 demonstrate that in three crops (crops A, B and D) a significant improvement in celery-edible yield resulted where storage was in controlled atmosphere. The improvement in edible yield was due to a reduction in spoilage with a resulting reduction in trimming loss. The principal spoilage reduced was the soft rot type. A search of the literature has failed to show any previous research where a statistically significant reduction in spoilage was ascribed to controlled atmosphere. The effect of low-oxygen atmosphere on soft rot in celery is not conclusive and should be studied further. The fourth crop was celery hearts which had the least amount of spoilage. This could have been due to either crop variability or an inherently longer shelf-life in celery hearts. The data in this report show that wrapped celery lost less moisture than unwrapped celery. This confirms previous packaging studies (7) which showed that the weight losses, principally through evaporation, of unwrapped or parchment wrapped celery were large enough to result in wilted celery.

Previous reports on lettuce (15) and tomatoes (17) have shown that in order to defray the additional cost of a commercially available controlled atmosphere system such as TECTROL, a reduction in fresh produce loss of 1% to 5% was required. The cost analysis estimate (Table 7) indicates that an improvement of 2.5% to 4.7% in celery yield is required to defray the additional cost of TECTROL controlled atmospheres in refrigerated containers or rail cars used for shipping celery. It further indicates that the additional cost of TECTROL controlled atmosphere would be negligible compared with procurement and shipping costs involved in shipping fresh produce.

A review of the literature has indicated that significant benefits in terms of improved quality, reduced decay and extended shelf-life resulted where controlled atmosphere was used for storing or shipping many fruits and vegetables.

It is concluded that there is sufficient information to warrant a series of field tests on celery and other fresh fruits and vegetables shipped in commercial controlled atmosphere containers to military organizations overseas.

Table 7. Cost Analysis Estimate

Shipping Unit	Celery crates per unit* (number)	Point-to-Point shipping locations	Transportation Cost per shipping unit* (dollars)	Cost of celery** (dollars)	Additional cost TECTROL per shipment (dollars)	Celery Loss Reduction to defray TECTROL cost*** (percent)
24-foot Container	395	West Coast to Hawaii	$803.00	$2,172.50	$93.00	4.28%
20-foot Container	327	West Coast to Subic Bay	1,411.00	1,798.50	85.00	4.73
20-foot Container	327	West Coast to Guam	1,473.00	1,798.50	85.00	4.73
24-foot Container	395	West Coast to Japan	2,285.00	2,172.50	93.00	4.28
35-foot Container	556	West Coast to Republic of Vietnam	2,610.00	3,058.00	115.00	3.76
Rail Car	1269	West Coast to East Coast	302.00	6,979.50	175.00	2.51
40-foot Container	682	East Coast to Mediterranean (as Naples)	2,590.00	3,751.00	125.00	3.33
40-foot Container	682	East Coast to Europe (as Rotterdam)	1,886.00	3,751.00	125.00	3.33

* Estimated

** Cost based on $.10/lb celery

*** Minimum reduction in celery loss required to defray additional cost of TECTROL per shipment; based on $.10/lb celery

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13. ABSTRACT

Laboratory tests were conducted to determine the effect of controlled atmosphere on celery. Storage periods were 3 to 8 weeks. The data indicates that the use of controlled atmosphere results in celery which is greener in color, more turgid and of more intense celery flavor.

Significant reductions in spoilage of the soft rot type were found in celery which had been initially stored in controlled atmosphere. However, spoilage data were limited to 3 crops of celery only and must be viewed with caution. The fourth crop as represented by celery hearts, exhibited the least amount of spoilage. The data in this report also show that wrapped celery lost less moisture than unwrapped celery. The break-even point to defray the additional cost of a commercially available controlled atmosphere method of shipping is estimated to be in the range of 2.5% to 4.7% improvement in celery yield.

It is concluded that sufficient laboratory data, and information in the technical literature, is available to warrant a series of field tests on celery and other fresh fruits and vegetables shipped in commercial controlled atmosphere containers to military organizations overseas.

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